An Investigation of Mechanisms by which Wave Cyclones Transport Pollution to the Western Pacific

Spring 2001 NASA-GTE-TRACE-P

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Introduction and Motivation

- Study motivated by need to understand complexities of air flow through Pacific cyclones
  - Pollution transport from Asia during late winter/early spring intimately related to transient mid-latitude cyclones and their associated circulations
    - **Conveyor belts**, (prefrontal) convection, **frontal circulations**, topographic effects, etc.
  - Greater understanding of processes and interaction among scales needed for most accurate interpretation of chemical data
  - Very interested in the intricacies of air flow within these systems

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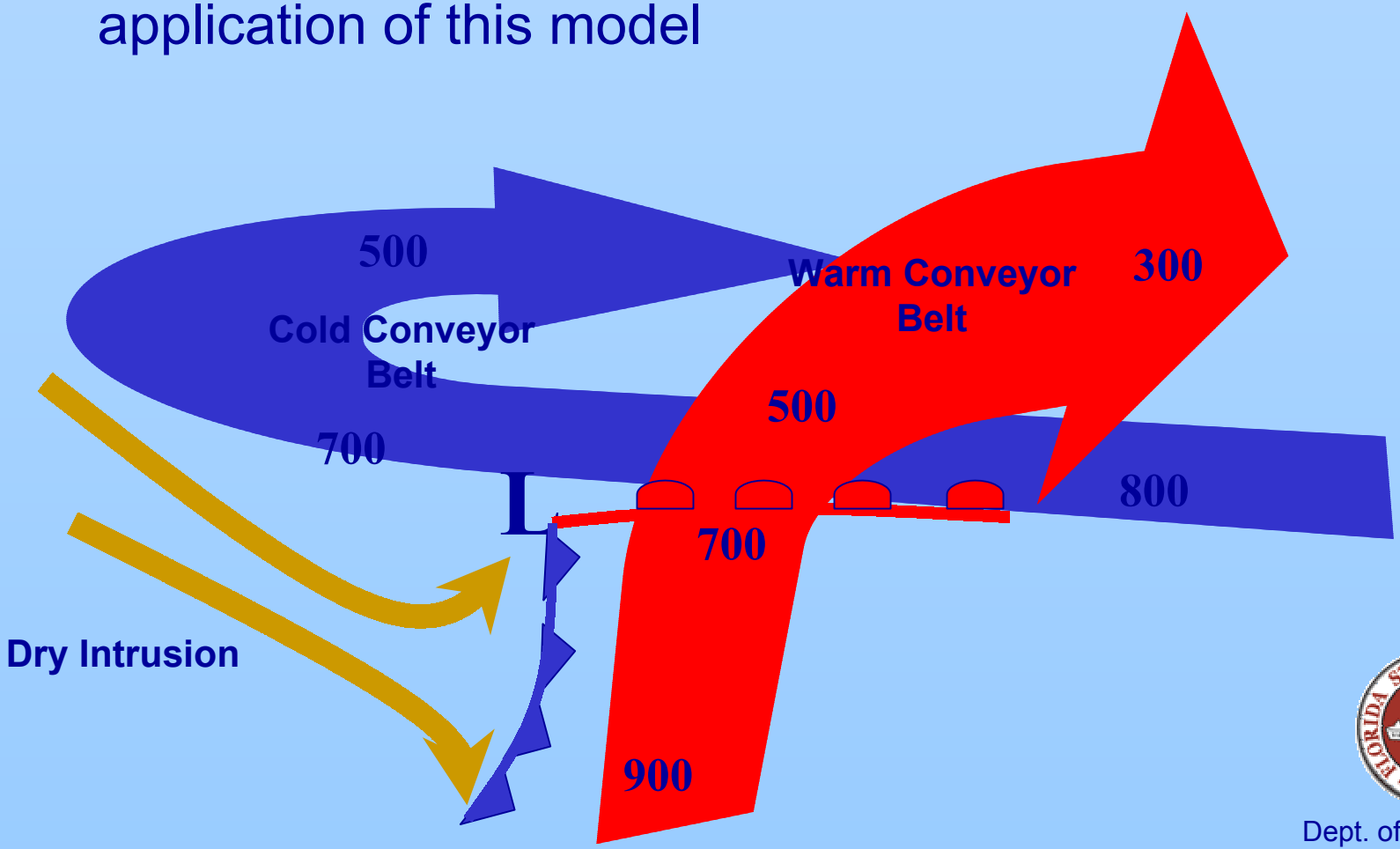
Air Flow in Mid-latitude Cyclones

- Simplified 3 air stream model (after *Carlson*, 1980)
- More complex in actuality; much debate about application of this model



Air Flow in Mid-latitude Cyclones

- Recent treatment of conveyor belts:
  - Modifications of classic model to include other air streams.
    - Particularly cyclonic appendages of both the warm and cold conveyor belts
      - *Young*, 1989; *Bader et al*., 1995; *Cooper et al*., 2001
  - "Fanlike" spreading of air streams rather than conveyor belts.
    - No basis for use of conveyor belt terminology
      - *Kuo et al*., 1992
  - Air stream boundaries and "coherent ensembles" of trajectories identified with numerical techniques.
    - Removes subjectivity from analysis process
      - *Cohen and Kreitzberg*, 1997; *Stohl,* 2001

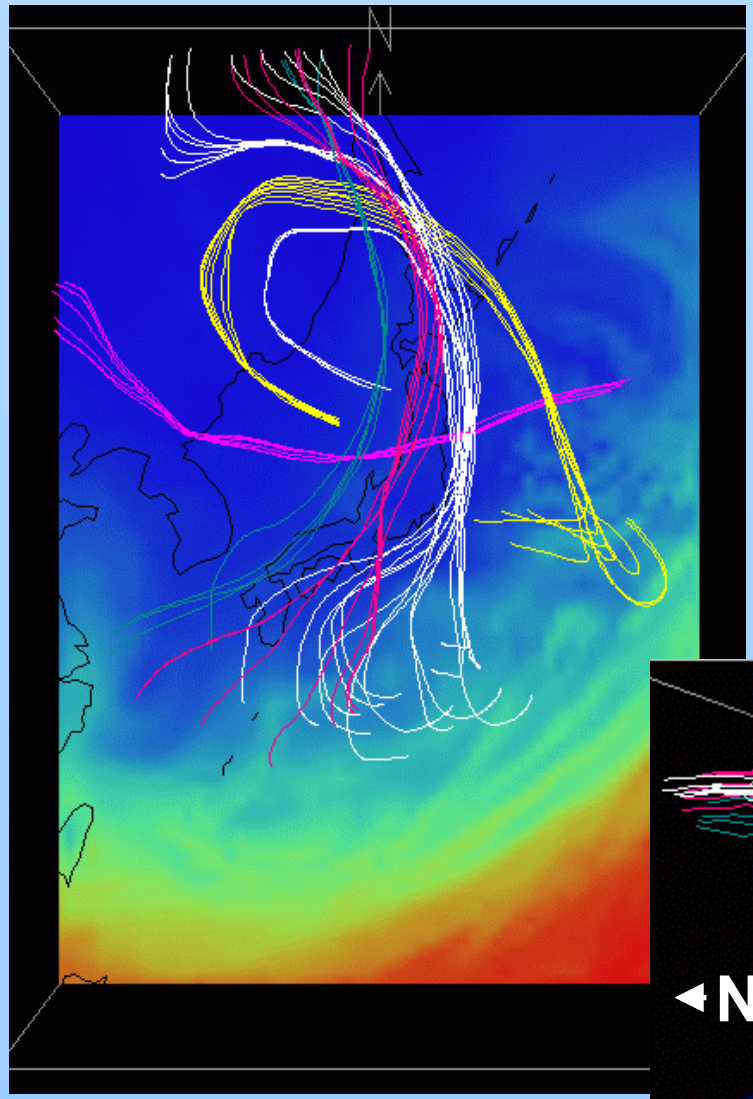
Conveyor Belts

- Synoptic scale features lengthwise
  - 1000's km
- Mesoscale-synoptic scale in width
  - 100's km
- Shallow vertical extent
- Past studies have employed data of resolutions which may not be suitable for accurate depiction of these flows
  - i.e. Too coarse in the horizontal or vertical, insufficient temporal resolution

Conveyor Belts

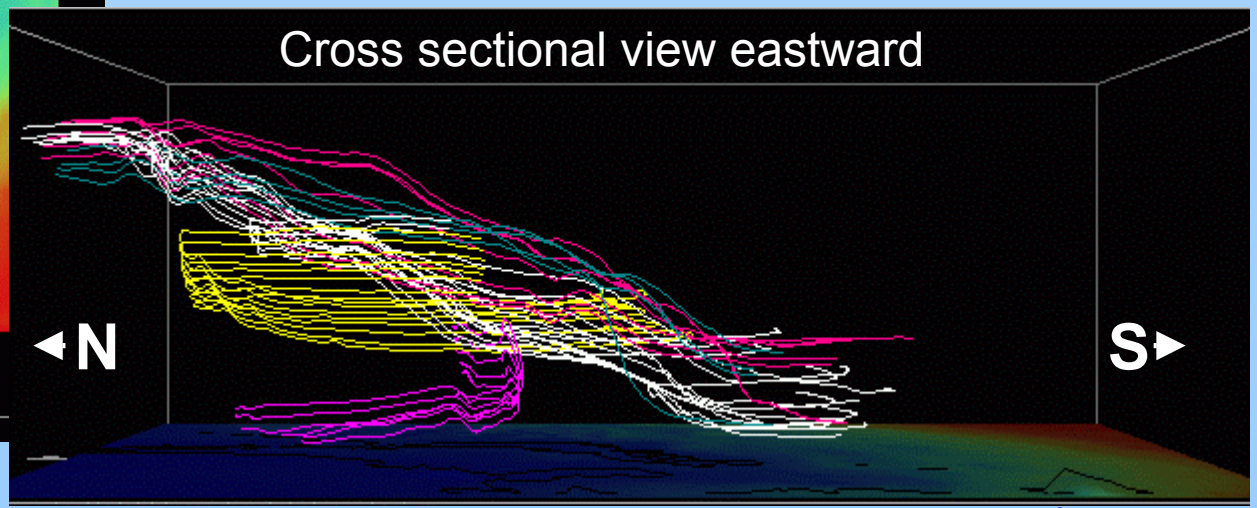
- We will employ mesoscale numerical modeling capabilities to investigate the suitability of the conveyor belt description of air flow with respect to cyclones during TRACE-P
  - Higher resolution simulations than in previous studies
    - Sub 20 km horizontal grid spacing
    - High resolution boundary layer and mid-tropospheric vertical layering
    - Hourly model output - particularly important for trajectory calculations w/r/t small spatial/temporal features

Flows Within March 04 Cyclone

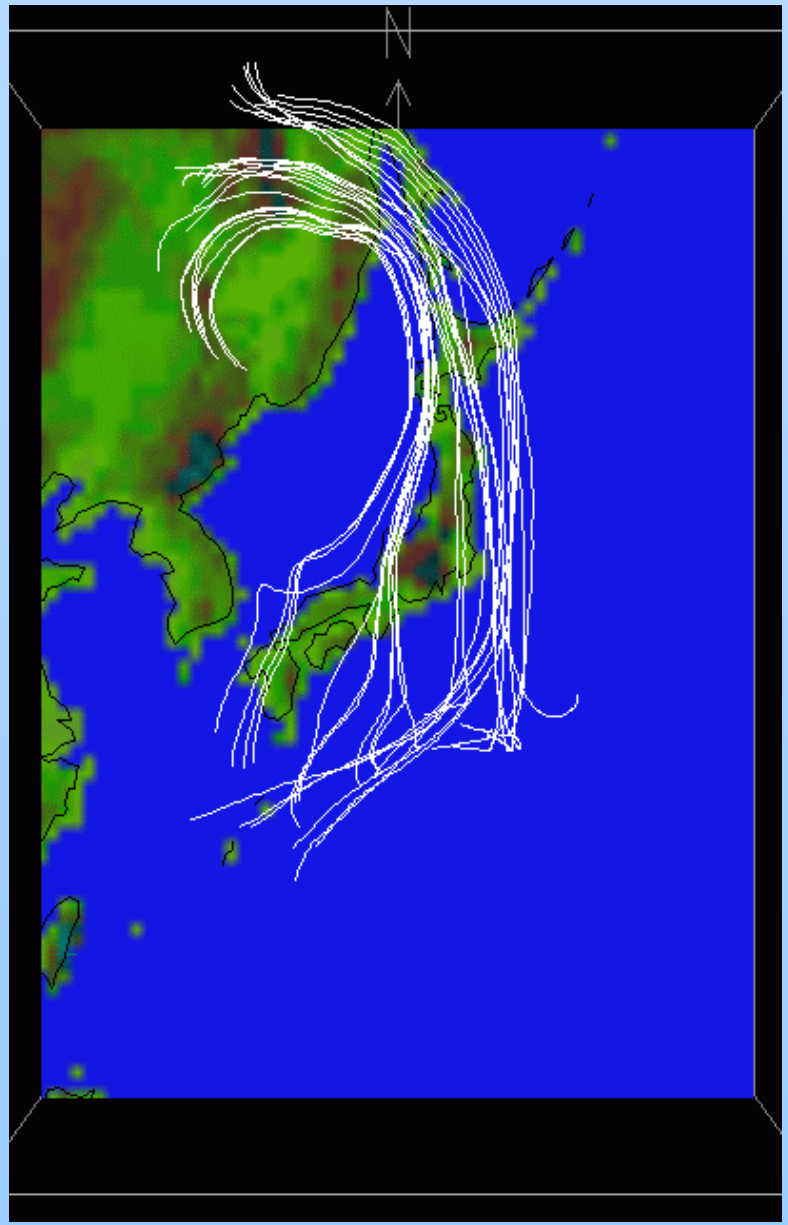


0303 00 UTC - 0305 12 UTC

- Evidence of cyclonic extensions of both warm and cold conveyor belts
- Classic upper-level anticyclonic path of warm conveyor belt *only*
  - Based on wind data generated by MM5 at 25 km horizontal resolution



Effect of Terrain



- Initial simulations indicate a splitting of the warm conveyor belt as it travels over Japan
- Similar patterns over higher elevations in Asia

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Cases for Simulation

- Selection of cases
  - 6 cases from 4 March - 4 April 2001
  - Based on cyclone locations w/r/t aircraft positions
    - Sampling of various sectors of cyclones in different stages of development
- Case specifics:
  - 1) March 04 - Guam to HK transit
    - Cold frontal crossing
      - WCB, post-cold frontal BL outflow
  - 2) March 07 - HK #1, March 09 - HK #2
    - Cold frontal crossing
      - Post frontal outflow on day 2

Cases for Simulation

- Case specifics (cont.):
  - 3) March 17 - HK to Okinawa, March 18 - Okinawa to Yokota
    - Cold frontal crossing w/ sampling on consecutive days
  - 4) March 21 - Yokota #1
    - Multiple frontal crossings
  - 5) March 31 - Yokota #5
    - Dual lows, recirculation
  - 6) April 04 - Yokota to Kona transit
    - Cold frontal crossing
      - Aged air mass

Model Simulations

- PSU/NCAR MM5 - Version 3
- Non-hydrostatic
  - Reduction of vertical pressure gradient force errors at smaller grid resolutions
- Terrain-following vertical sigma coordinate
  - Variable vertical grid spacing with higher resolution in the boundary layer and mid-troposphere

Model Simulations

- Two-way nested grid configuration
  - 180, 60, 20, 6.67 km likely
  - Information shared between nests
- Initialized with ECMWF global analyses
- Physical and dynamical parameterization schemes chosen according to grid resolution
- Simulations of 48 hours

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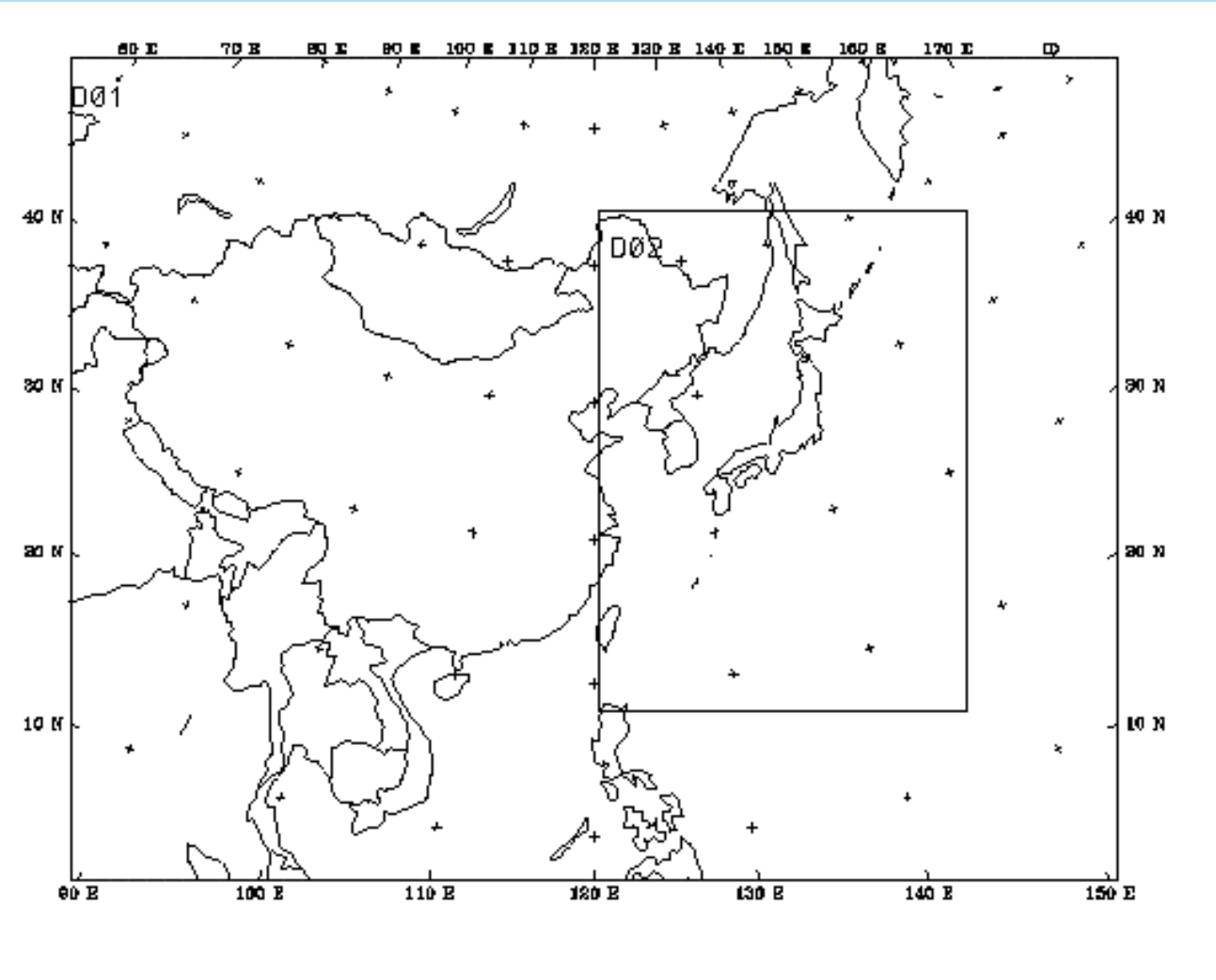
MM5 Domain



- Domain configuration from a particular test simulation
  - Animations
- Outer grid 75 km
- Inner grid 25 km
- Encompasses region of cyclone development

Meteorological Products

- Many parameters and products produced by MM5 and various post-processing applications to aid in study, including:
  - Directly from model:
    - Air mass indicators such as PV, potential temperature, humidity variables
    - Wind data, convective/non-convective precip, etc.
  - Calculated from model output:
    - Kinematic air trajectories, contraction rates & air stream boundary information (Lyapunov exponents)
  - Additional met data
    - Satellite imagery, aircraft data

Integration of Met and Chemistry

- Concurrent meteorological and chemical data provides a much more comprehensive understanding of transport processes than when used alone.
- Chemical measurements serve as a constraint of meteorological data (and vise versa).
  - Do wind data and chemistry match up?
  - Do transport processes explain chemical signatures?

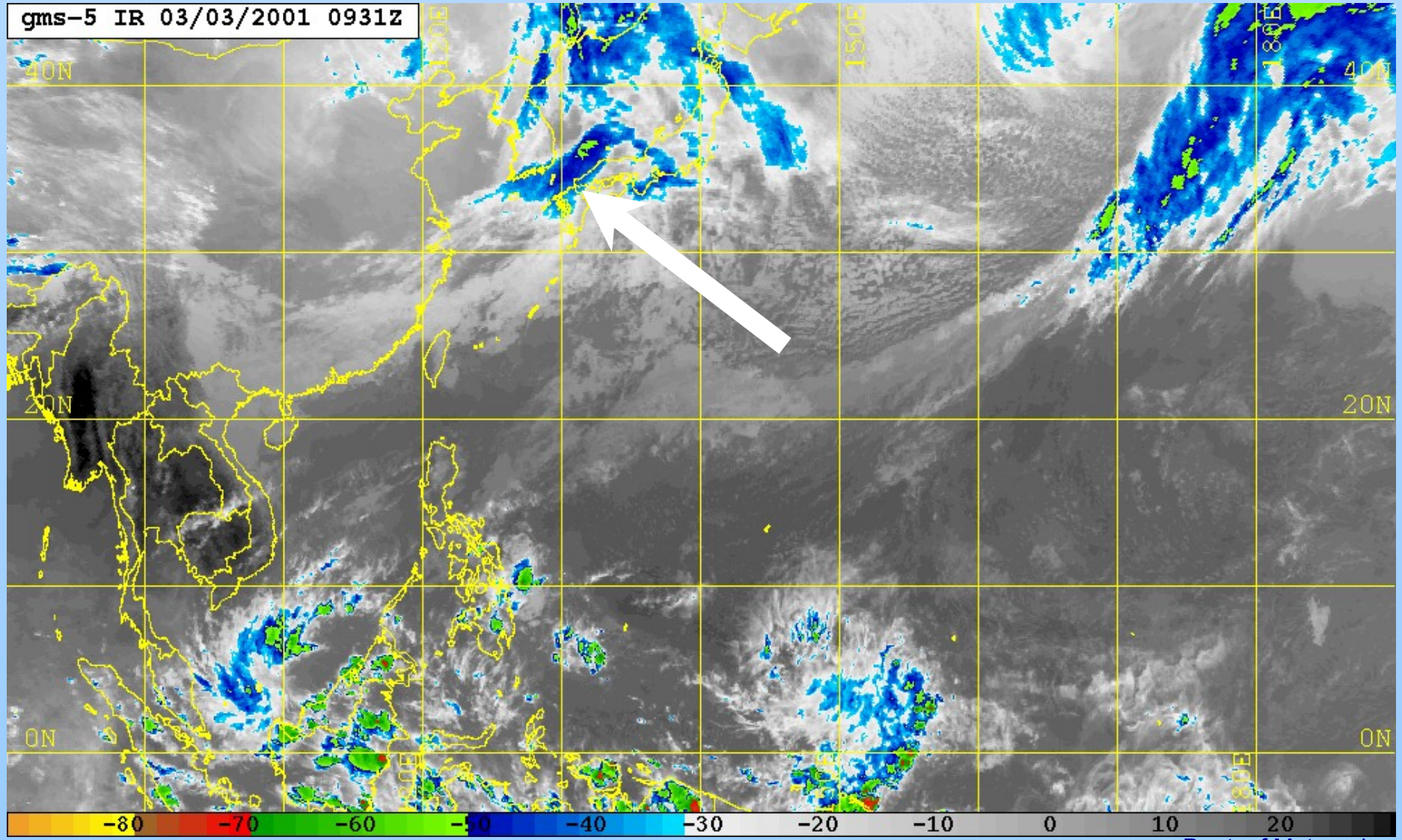
Objective Specifics

- **1)** Determine if the classic conveyor belt model accurately depicts flow patterns within cases of interest
- **2)** Identify roles of various transport mechanisms in modeled cyclones as they relate to pollution transport to the free troposphere
  - Trajectories, trajectory products, ascent/descent criteria, quasi-conservative meteorological quantities along trajectories (e.g., PV, q, θ)
  - GOES-8 and GOES-10 imagery
  - Chemical information

Objective Specifics

- **3)** Examine the importance of scale interactions as they relate to chemical transport
- **4)** Examine the time evolution of large-scale transport processes and the exchange of pollutants among adjacent systems.
  - Anticyclonic return flow into WCB of upstream cyclones
    - Aged air mass sampling
  - Extension (in time) of trajectory products

IR - 2001 0303 0931 UTC



Current Status

- Cases to be simulated have been chosen
  - Initial model simulations are being conducted
  - Grid configurations, physical and dynamic parameterizations
  - Comparisons with ECMWF analyses, GOES-8 and 10 satellite imagery
    - Proper placement/propagation of features etc.
    - Minimization of boundary error influence on simulations
- Next:
  - Model simulations and initial data analyses
  - High resolution trajectories from MM5 data
  - Initial chemical/met analyses

An Evaluation and Intercomparison of CO from Chemical Transport Models

Chris Kiley
Henry Fuelberg
Chemical Modelers

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Objectives

- Few intercomparisons in the literature
  - Jacob, D.J. et al. 1997
  - Rasch, P.J. et al. 2000
- Relate model-derived CO to aircraft-derived CO for as many flights as possible
- Consider initial CO analyses--not forecasts
  - Not interested in quality of weather forecasts
- Hypothesis: A model's meteorology will affect its resulting CO values
  - Deep Convection
  - Boundary Layer Processes
  - Conveyor Belts

Several Global and Regional Models

- Greg Carmichael--Univ. Iowa
- Daniel Jacob/Paul Palmer--Harvard
- Celine Mari--Aero-France
- Ken Pickering/Dale Allen--Univ. Maryland
- Brad Pierce--NASA Langley
- Michael Prather--U. Calif. Irvine
- Martin Schultz--Max Planck

Details

- Many details to decide at Break Out Session
  - Which flights to examine?
  - What CO inventories being used?
  - Transfer of data to FSU
  - Etc.
- We are very open to suggestions